STRENGTH TEST ON OPTICAL FIBERS TO BE USED IN VLPC

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OPTICAL FIBER STRENGTH TEST

Objective

To determine the strength of the optical fibers to be used in the VLPC cassette.

Summary

Strength tests were done on optical fibers that are to be used in the VLPC cassette. A number of the fibers will hang vertically and support a suspended copper isotherm. Concern was expressed over whether one fiber could support the entire weight of the isotherm (8 ounces) if uneven shrinkage of the fibers occurs at cryogenic temperatures. The fibers have a polystyrene core and testing done at room temperature showed that one fiber can support the isotherm with a factor of safety of 13.2 before fracture will occur from a uniaxial load. Data in <u>Cryogenic Engineering</u> by Scott shows that the strength of plastics increases (although polystyrene is not listed) as they are cooled. Two tests done to the fibers with liquid nitrogen support this. The safety factor of 13.2 will only increase at cryogenic temperatures. These results were determined through three tests whose summaries follow.

Test 1

Procedure

Test 1 was carried out at room temperature. The optical fibers were cut into 15" lengths, taken randomly from a number of different samples of the fiber. The tip of an old mechanical pencil was used to grip the fiber at one end. The weights were then slipped down the fiber until they came to rest on the pencil grip. The top of the fiber was then clamped to a fixed surface so the sample could hang freely. Weights were then added to the fiber until failure resulted. This was done repeatedly until the maximum load the optical fiber could carry was determined.

Results

fiber	weight suspended	results/comments:
1	5.96 lbs	Fractured after 3 min. into a number of pieces.
2	5.96 lbs	Fractured after 4.5 min. into a number of pieces. Difficult to determine which fracture is the original and which resulted from the fall.
3	5.96 lbs	Fracture after 2.25 min.
4	5.96 lbs	Fractured after 41 sec.
5	5.96 lbs	Fractured after 42 sec.
6	5.35 lbs 5.66 lbs	No fracture after 20 min. 0.31 lbs added. Fractured 36 sec. later.
7	5.35 lbs	No fracture after 15 min. 0.17 lbs added.

	5.52 lbs	No fracture after 7 min. 0.15 lbs added.
	5.67 lbs	Fractured immediately.
8	5.67 lbs	Fractured after 6.7 min. Study of the sample shows that of the three fractures, only one has an interesting shape. Two of the fractures resemble cross-sections where the third has a thinning cone shape. Inspection of previous samples shows similar breakage on a number of them. I begin to suspect that the fracture at failure is occurring under the grip of the mechanical pencil.
9	5.67 lbs	Fractured after 2.3 min. Test verifies that cone-shaped fracture does take place under pencil grip.

Discussion

Test 1 narrowed the maximum load capacity per strand of optical fiber to approximately 5.5 lbs. Although this gives a factor of safety of 11, I began to suspect that the grip of the mechanical pencil was contributing to premature failure of the fiber. I felt better results could be achieved by replacing the pencil grip with a mount that would be glued into place. This would reduce the triaxial stress created by the pencil grip to a uniaxial stress that better resembles the application of the fiber in the VLPC. Fibers with glued mounts were tested in Test 3. The setup for Test 2 repeated Test 1 but was carried out with LN2.

Test 2

Procedure

LN2 was used to cool the fibers in Test 2. The optical fibers were cut into 15" lengths, taken randomly from a number of different samples of the fiber. The tip of an old mechanical pencil was used to grip the fiber at one end. The weights were then slipped down the fiber until they came to rest on the pencil grip. The top of the fiber was then clamped to a fixed surface so the sample could hang into a dewer holding LN2. Weights were then added to the fiber until failure resulted.

Results

fiber	weight suspended	results/comments:
1	5.70 lbs	No fracture after 15 min. In an attempt to add more wt. the sample broke.
2	5.96 lbs	No fracture after 15 min. Broke in an attempt to add more weight.

Discussion

The setup of this experiment was very awkward because the diameter of the dewer restricted my ability to work with the sample. Only the bottom 3 inches of the fiber were immersed in the LN2. Therefore the temperature of the fiber during the test varied linearly along its length from approximately 77° K to room temperature. Under these conditions of reduced temperatures, fiber 1 carried more weight than was achieved in Test 1, and it held it for 15 min. Fiber 2 carried a record load of 5.9 lbs for 15 min. I feel the fractures of the two fibers were not the result of the loading but the result of the disturbance put into the wire in my attempt to put the load in place. It seems the fibers broke because the colder temperatures made the fiber more brittle. Under the limited testing done with the fibers at lower temperatures, the fibers achieved a measured factor of safety of 11.8.

Test 3

Procedure

Test 3 was carried out at room temperature. The optical fibers were cut into 15" lengths, taken randomly from a number of different samples of the fiber. Pieces of Torlon 1553 were glued to the end of the fiber for the weights to rest on. The glue used is Scotch-Weld 3535 B/A Urethane Adhesive manufactured by 3M. The weights were then slipped down the fiber until they came to rest on the Torlon. The top of the fiber was then clamped to a fixed surface so the sample could hang freely. Weights were then added to the fiber until failure resulted. This was done repeatedly until the maximum load the optical fiber could carry was determined.

Results

fiber	weight suspended	results/comments:
1	5.96 lbs	No fracture after 20 min. 0.35 lbs added.
	6.31 lbs	No fracture after 7.5 min. Fiber then broke in an attempt to add more weight.
2	7.5 lbs	Fracture after 33 sec.
3	6.31 lbs	No fracture after 16.5 min. Fiber then broke in an attempt to add more weight.
4	6.6 lbs	No fracture after 20 min. 0.6 lbs added.
	7.2 lbs	Defects become apparent and fracture occurs after 20 sec.
5	6.6 lbs	No fracture after 10 min. 0.4 lbs added.
	7.0 lbs	Defects become apparent. 0.2 lbs. added.
	7.2 lbs	Defects growing. Fracture after 20 sec.

Discussion

Although the fiber could hold an ounce or more over 6.6 lbs., I chose 6.6 lbs. as the maximum load because no visible defects occurred at this weight. Test 3 gives the optical fiber a factor of safety of 13.2. Note that the maximum load the fiber could carry increased by more than 18% from Test 1 simply by using glue to replace the pencil grip to hold the weights on the fiber. This same glue will be used in the VLPC to hold the fibers to the isotherm.

It occurred to me that although I had correctly modeled the way the fibers will be attached to the isotherm, I did not consider how the fibers will suspend from the top of the cryostat. In all three tests, the fibers were suspended from a clamp. Recall that in Test 1, I determined that the clamping from the pencil grip used to hold the weights to the fiber led to premature failure of the fiber. Upon viewing the fiber samples used in Test 3, I did not notice the same necking and thinning of the fibers that resulted from the pencil grip in Test 1 and Test 2. Because of this, I am inclined to think that failure of the samples in Test 3 was not contributed to by my suspension clamp and that the recorded numbers for the maximum load are valid. The suspension clamp gripped the top half inch of the fiber's length. The clamp distributed its lateral load over an area of the fiber considerably greater than the wieght grip did. So necking, and therefore weakness of the fiber, did not result from the suspension clamp. Also notice that in my 'result/comments' column of the data that visible defects are starting to appear throughout the sample as the maximum load is approached. I feel the fractures occurred at the sites of some of these defects within the fibers.

Conclusion

Strength tests done at room temperature on the optical fibers to be used in the VLPC cassette indicated that a single fiber can support the weight of the eight ounce copper isotherm with a factor of safety of 13.2 when a uniaxial load is applied. Data found in Cryogenic Engineering by Scott and two tests done to the fibers with liquid nitrogen indicate that this factor of safety will only increase when cooled to cryogenic temperatures.